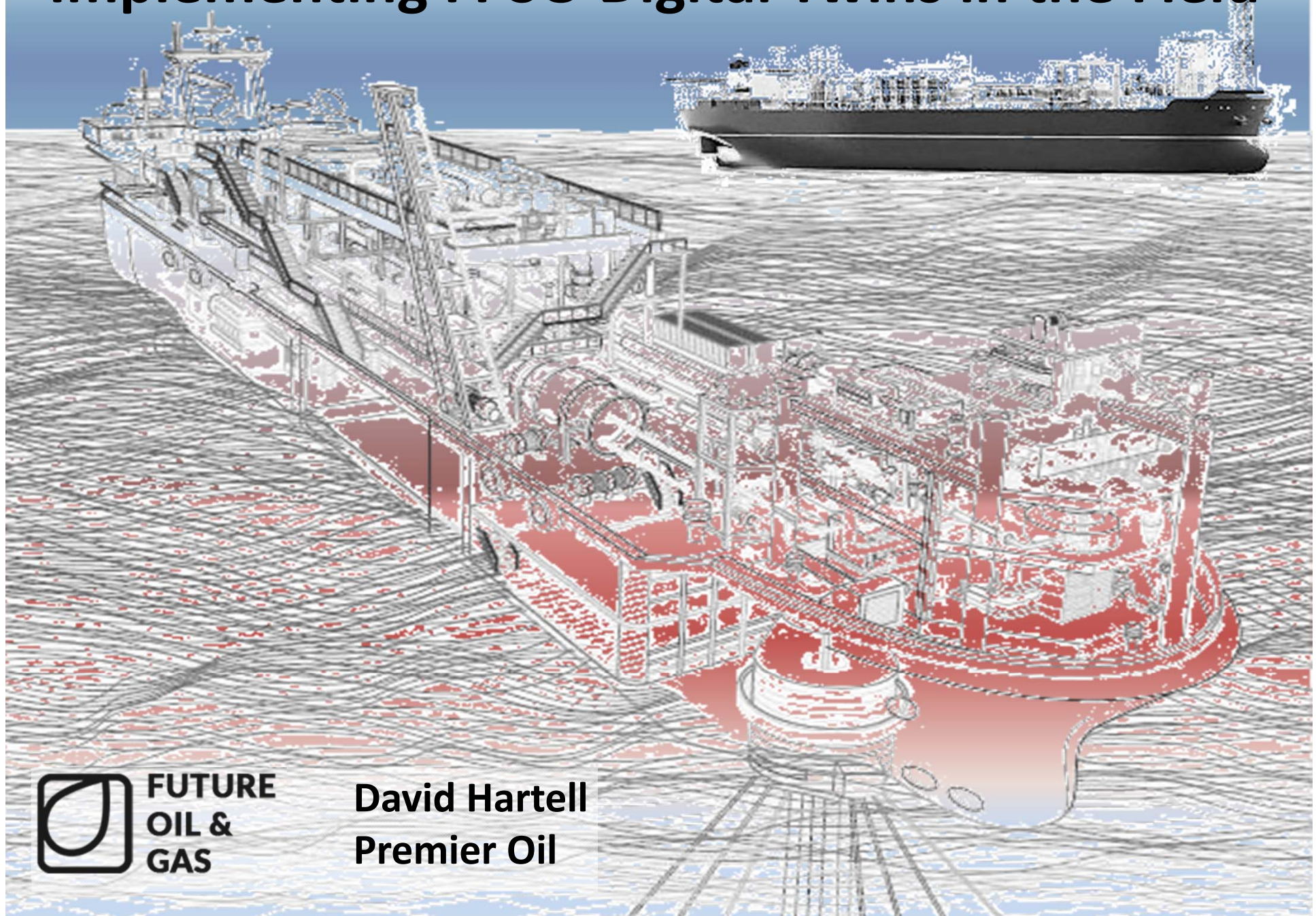


Implementing FPSO Digital Twins in the Field



**FUTURE
OIL &
GAS**

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Premier Oil**

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Digital Twins

A Digital Twin consists of several key elements and features:

1. A virtual, dynamic simulation model of an asset;
2. The model is initialized based on the original design and is updated during procurement (vendor data), construction (as-builts), pre-commissioning, commissioning, start-up, and operations to stay aligned with the physical asset;
3. The physical asset is instrumented with sensors which can capture its current operational state.

“A digital twin allows analysis of data and system monitoring in a way that dramatically improves operations, preventing downtime, reducing maintenance costs, and providing data that can be used to streamline operations throughout the lifecycle of the asset.” - DNV GL

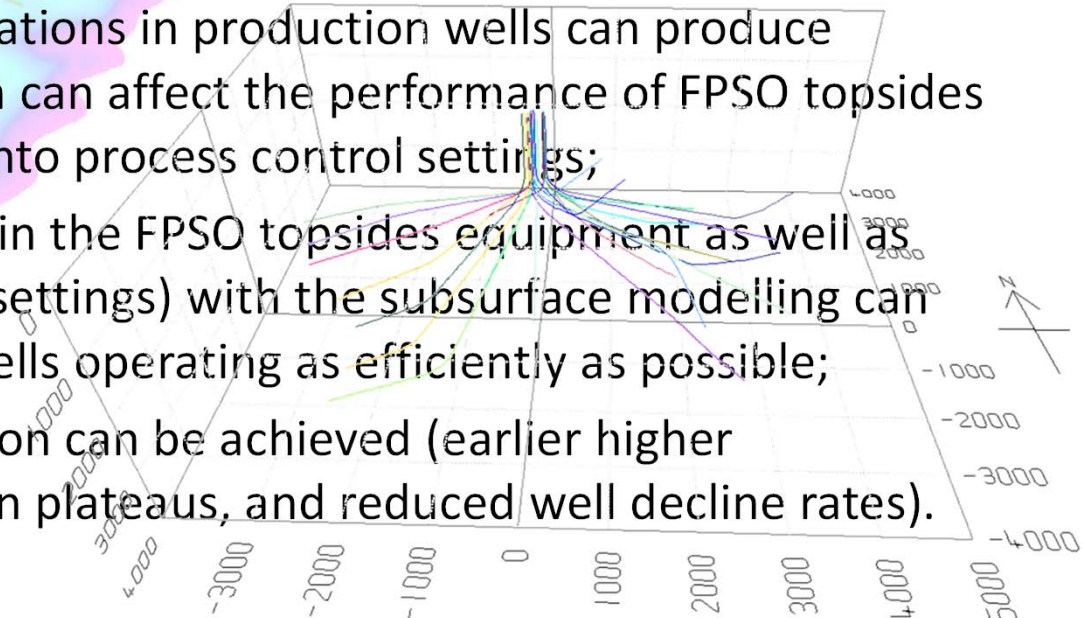
Digital Twins

- Design Phase (Subsurface Modelling, Process and ICSS Design)
- Pre-Operations Phase (Procurement / Construction / Pre-commissioning / Commissioning / Operator Training)
- Operations Phase (“in the Field”)

“The physical and digital worlds are converging. With machines and people in better communication, insights can be achieved to make smarter decisions.” - GE

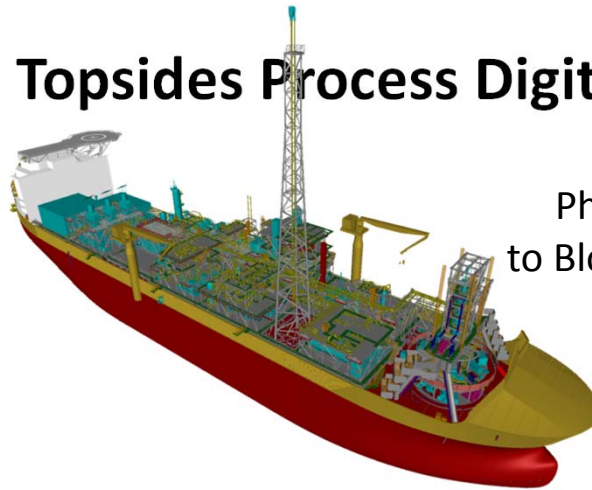
Subsurface Modelling

- One of the first priorities is to have a digital twin simulation model of the subsurface with all reservoir inputs (water and gas injection wells) and outputs (production wells) including subsea facilities boundary conditions like gas lift, well chokes, line parameters, and any rate constraints;
- A complex reservoir with gas lift of production wells, horizontal production wells, water injection wells both in the aquifer and oil legs, and gas injection wells can produce varying outputs which need to be optimised to obtain better oil production, with less water and free gas production;
- In such a reservoir, gas fluctuations in production wells can produce hydrodynamic slugging which can affect the performance of FPSO topsides and therefore require input into process control settings;
- Tuning all these parameters (in the FPSO topsides equipment as well as the subsea wells equipment settings) with the subsurface modelling can assist with keeping subsea wells operating as efficiently as possible;
- Up to 6-8% more oil production can be achieved (earlier higher production, longer production plateaus, and reduced well decline rates).

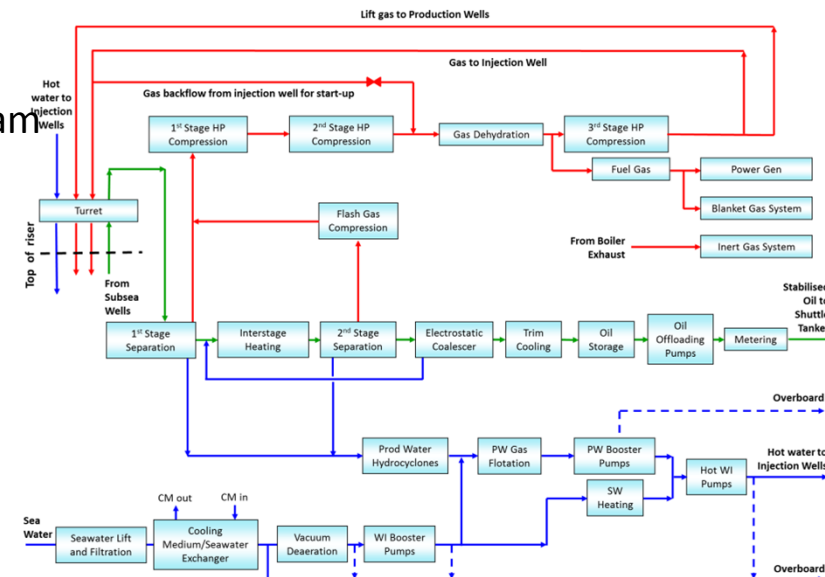


FPSO Process Design

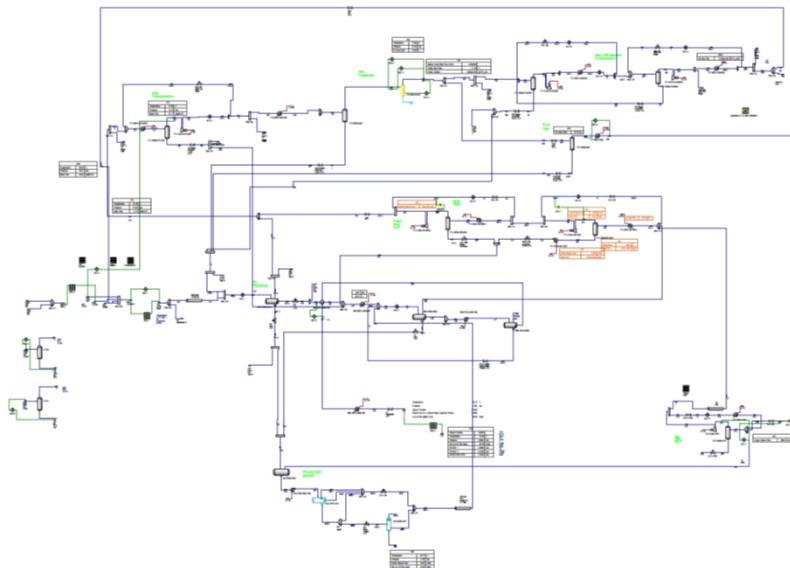
- Topsides Process Digital Twin



Physical Concept
to Block Flow Diagram



Block Flow Diagram
to Process Simulation Model
(Dynamic Aspen HYSYS or Kongsberg K-Spice)

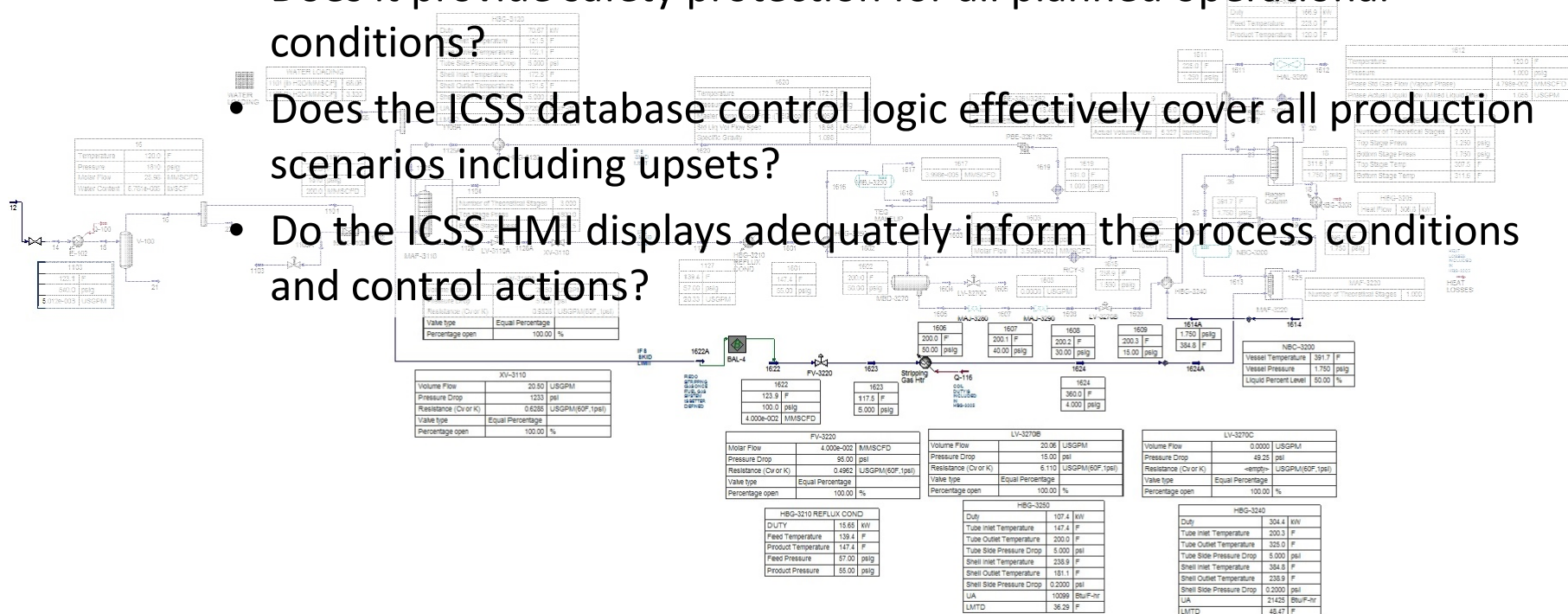


FPSO Process Design

- **Topsides Process Digital Twin**
 - Each segment of the process is modelled in detail with significant instruments and controls, pumps, valves, vessels, and piping etc.
- **Engineering Simulator**
 - Dynamic Simulation Model
 - Integrated Control and Safety Systems (ICSS) Operator Station
 - ICSS Emulation Software
- Safety systems hierarchy and logic modelled
- HMI systems conceptualised for initial modelling interface

- The resulting digital twin is able to be use for both Process design as well as Integrated Control & Safety System(ICSS) design:

- Is the design suitable for all rates and potential transient conditions?
- Does it provide safety protection for all planned operational conditions?
- Does the ICSS database control logic effectively cover all production scenarios including upsets?
- Do the ICSS HMI displays adequately inform the process conditions and control actions?



Pre-Operations Phase

- **FPSO Topsides Process Digital Twin**

- As each piece of equipment or system is procured, there are specific characteristics and results of factory testing that can be input into the models:
 - Do the Vendor Packages interface well with the process and ICSS?
 - Addition of Field Operated Devices panels / Error message panels;
 - Is the equipment protected under all operating and upset scenarios?
 - Pre-tune controllers and define alarm limits;
 - Are operating procedures correctly detailed for sequence durations to avoid unnecessary trips?
 - Can availability be improved?
 - Can we fully test operating procedures?

Pre-Operations Phase

- **FPSO Topsides Process Digital Twin**

- As the project proceeds, Operations team personnel will require training in how to operate the process systems;
- Operating Training Simulator (OTS)

Value:

- Operators: (1) improved understanding of the process and increased confidence on operating the process safely; (2) improved ability to handle process upsets; and (3) increased confidence and comfort in daily work;
- Engineering / Management: (1) faster production start-up; (2) reduced operation risk and enhanced facility integrity; and (3) higher production performance;
- Continuous improvement:
 - Improve ICSS settings and logic based on experience gained with OTS;
 - Improve HMI displays to provide better visualisation and ease of operator interactions after training feedback.

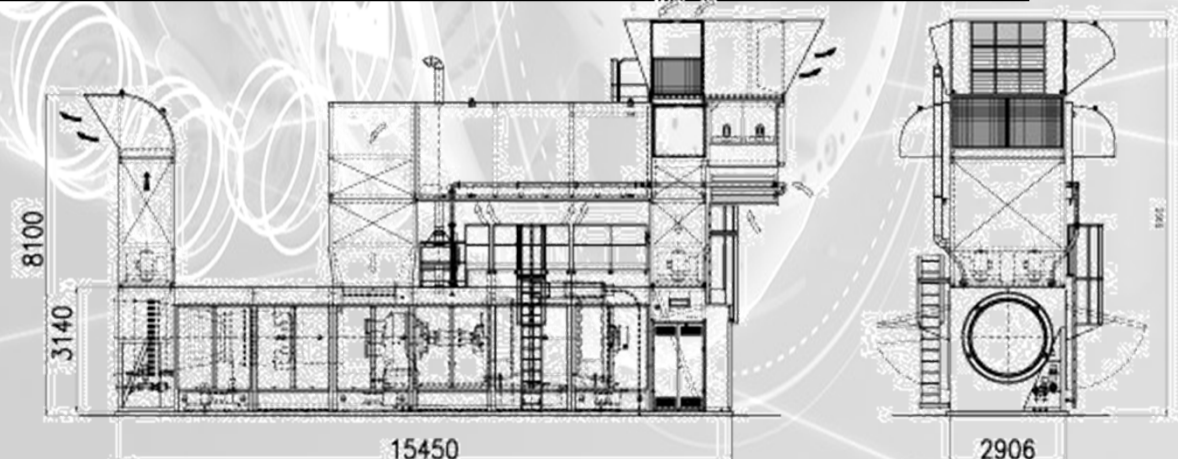
Reference: "Economic benefits of training simulators",
T. Komulainen, R. Sannerud, B. Nordsteien, H. Nordhus,
World Oil, December 2012

Operations Phase

- **FPSO Toppers Process Digital Twin**
 - **Case Example 1** - Data analytics for a gas turbine (power generation or mechanical drive)

Most common causes of degradation of offshore gas turbines:

- changes in blade surfaces due to fouling, and the effect on the blade aerodynamics
 - fouling can be eliminated by cleaning;
- changes in seal geometries and clearances, with resultant leakage flows and increases in absorbed power;
- changes in the combustion system (e.g. which result in different pattern factors);
- From these analytics we can adjust operating settings to accommodate observed degradations and work to extend maintenance timings to suit normal shutdowns.



Operations Phase

- **FPSO Toppides Process Digital Twin**

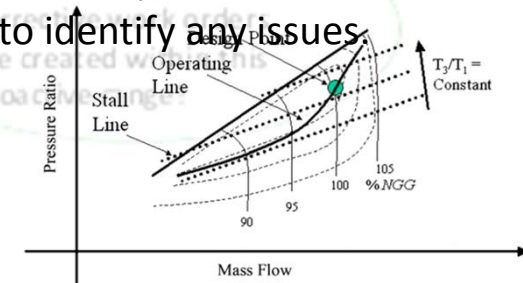
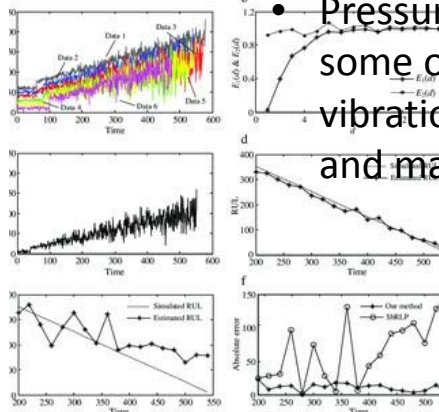
- How are we able to measure degradation?

- The Digital Twin process simulator will be predicting flow rates, pressures, and temperatures whilst actual recorded instrument data will provide comparative field values;

- Any differences would need to be explained, either by changing reservoir fluid compositions affecting the process or by some form of degradation to the process equipment and/or instrumentation:

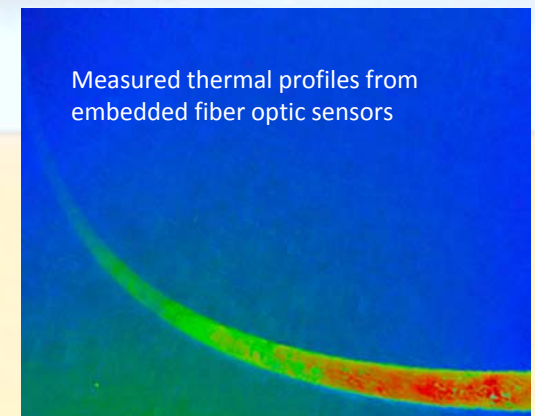
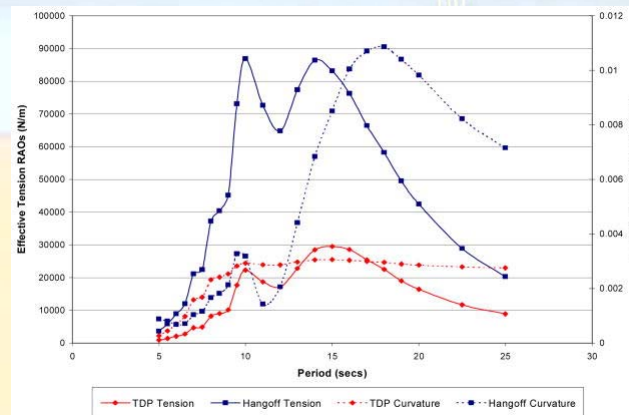
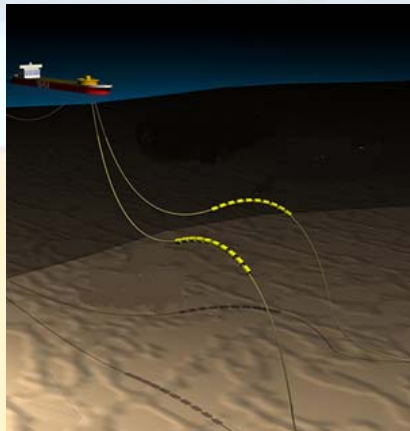
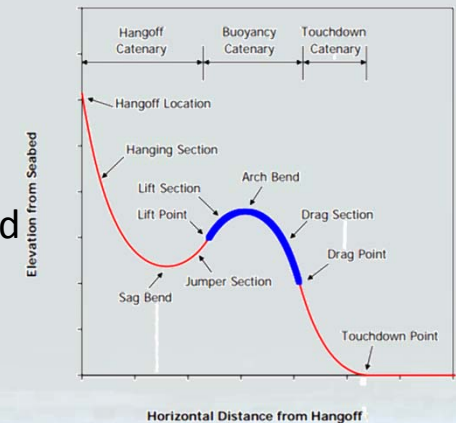
- mechanical wear, erosion, corrosion, or embrittlement;
 - scaling, fouling, wax or asphaltene depositions;
 - foaming, emulsions, hydrates;
 - vibration, mechanical interference, material deformation, fatigue;
 - instrument drift, instrument blockage, malfunction

- Pressure and temperature instruments (especially differentials) can help identify some of these degradations, but other instruments such as flowmeters, noise and vibration sensors, thermal imaging sensors, corrosion inspection (both automatic and manual scanning), and fluid sampling would be used to identify any issues



Operations Phase

- **FPSO Risers Digital Twin**
 - **Case Example 2** - Data analytics for the flexible risers that connect the FPSO to the subsea wells
 - Utilise turret buoy motions from actual metocean conditions;
 - Utilise measured wave spectra and current profiles;
 - Utilise measured internal flow characteristics (fluids, P, and T);
 - Calculate riser stresses compared with allowable stresses, and perform spectral fatigue analysis to estimate fatigue damage and remaining fatigue life; monitor ongoing fatigue performance;
 - With this information riser integrity can be better managed.

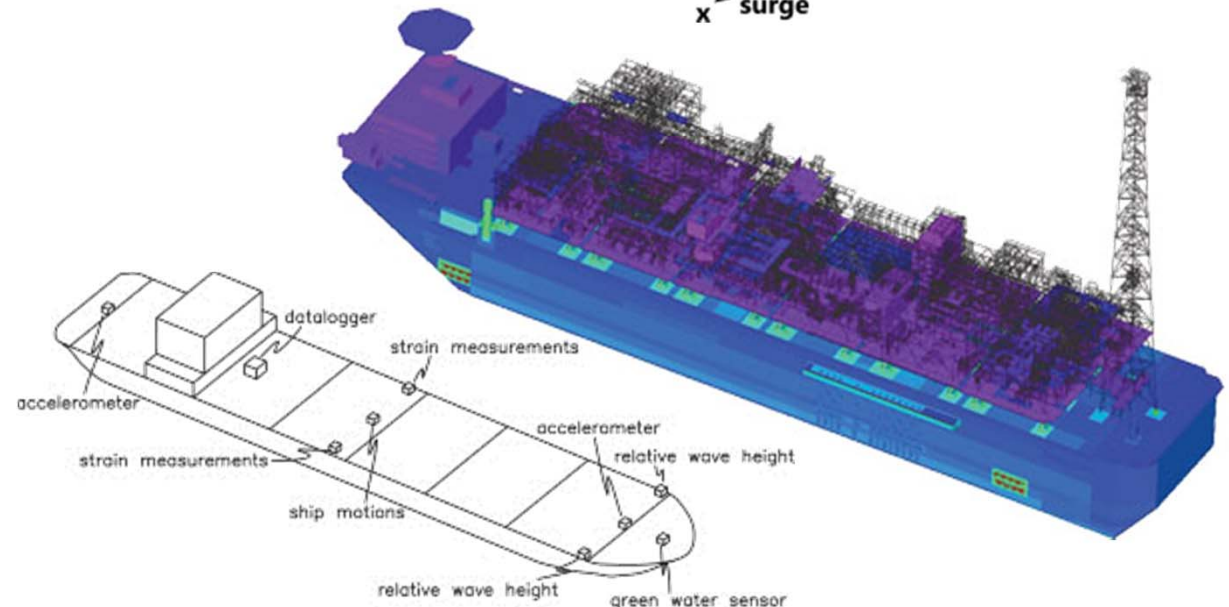
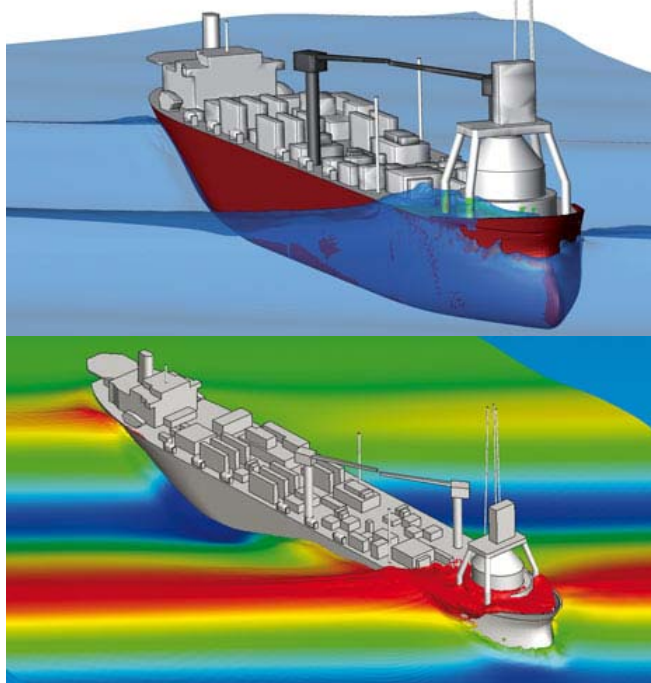
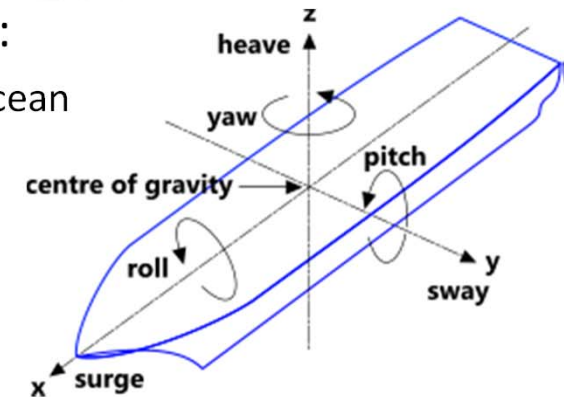
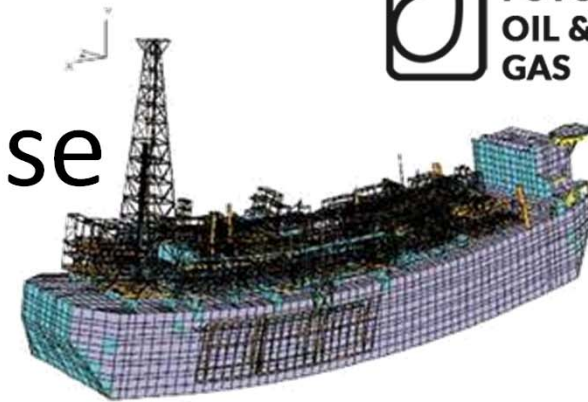


Operations Phase

- **FPSO Hull Structural Digital Twin**

- **Case Example 3** - Data analytics for the FPSO hull:

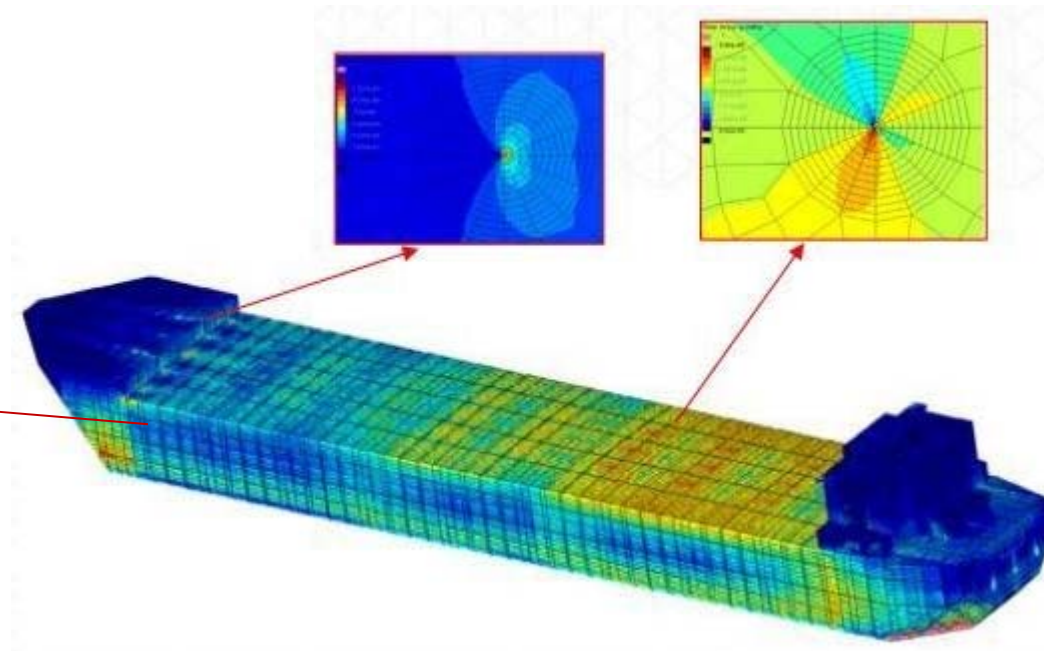
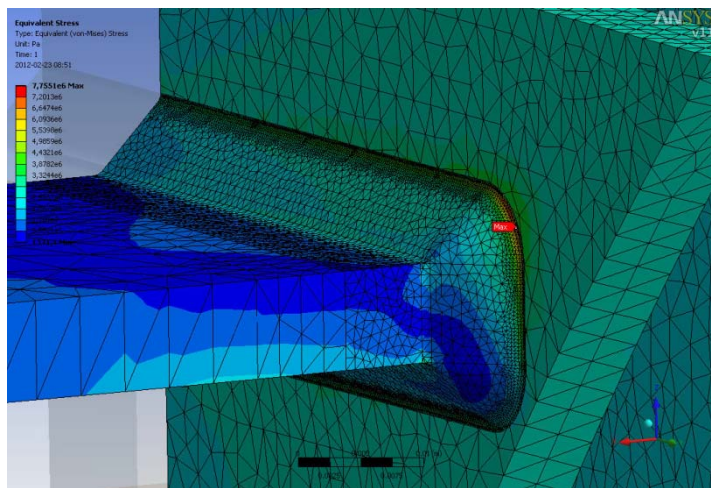
- Monitor and record ship motions and surrounding metocean conditions for use in virtual models;
 - Compare actual motions with predicted motions;
 - Compare actual strains with predicted strains.



Operations Phase

- **FPSO Hull Structural Digital Twin**

- Virtual models utilise ship motions to calculate hull stresses compared with allowable stresses, and spectral fatigue analysis is performed to estimate fatigue damage and remaining fatigue life;
- FPSO Asset Integrity Teams and Classification Societies would make use of these results to prioritise inspection activities, plan any required remedial work, and manage the asset integrity of the hull structure.



Subsea Modelling

- In the Subsea Facilities individual well flow rates and compositions are able to be measured using existing instrumentation;
- Virtual Flow Meters are a form of Digital Twin where pressure (P) and temperature (T) measurements can be used to estimate well flow rates and compositions in real time:
 - Assuming a gas lifted oil production well with multiphase production (oil, water, and associated gas);
 - Physical measurements used in these calculations include: (1) downhole P & T; (2) before well choke P & T; (3) after well choke P & T; (4) well choke position; (5) before gas lift choke P & T; (5) after gas lift choke P & T; (6) gas lift choke position; and (7) tree valve status (master, wing, and shutdown valves);
 - Up to five models are used to construct the virtual meter system: (1) near-wellbore reservoir model; (2) transient wellbore model; (3) well choke model; (4) gas lift choke model; and (5) well jumper model (optional);
 - Water cut meters (real-time measurements with near-infrared spectrum sensors to measure water cuts) would facilitate calibrating these models and improve accuracy of the predictions;
 - Real-time calibration programmes would use measured topsides total well flow rates and compositions to help allocate production back to the individual wells.
- The virtual flow meter results would be used with subsea flow assurance models of the jumpers, flowlines, and risers in stream/online analytics to help monitor start-ups, shutdowns, and potential wax and hydrate risks to ensure adequate mitigations are in place (control settings and chemical injection).

Holistic View

FPSO Facilities:

- FPSO Equipment and Production Systems Design (Topsides)
- OSIsoft PI System Architecture
- AVEVA Data Systems
- Operations and Maintenance of FPSO (Topsides)
 - Operations Philosophy and Execution
 - Computerised Maintenance Management System
 - Condition Monitoring / Condition Based Maintenance
 - Production Equipment and Systems Analytics (Topsides)
 - Asset Integrity Management System
 - Topsides Metering Utilisation
 - Offloading Co-ordination
- Operations of Subsea Equipment, Production Systems, Wells
 - Under the direction of Field Operator

Automation / ICSS:

- Production System Design Verification / Engineering Simulator (Topsides)
- Integrated Control & Safety System (ICSS) Design (Topsides)
- Control System Verification (Topsides+Subsea)
- Operator Training Simulator (part of Engineering Simulator)
- Production Equipment and Systems Analytics
- Real Time Production Optimization and Performance System (Topsides)

Subsea Facilities:

- (incl. Integrated Production Management System (PMS))
- Subsea Equipment, Controls and Production Systems Design
 - Flow Assurance Design (Subsea)
 - Subsea Systems Surveillance & Condition Based Maintenance
 - Virtual Flow Metering & Water Cut Metering (Subsea)
 - Production Management & Real Time Flow Assurance (Subsea)
 - Production Equipment and Systems Analytics (Subsea)
 - Subsea Maintenance Healthcare Contract (Option)
 - Reservoir Monitoring & Surveillance (Reservoir Management)

FPSO



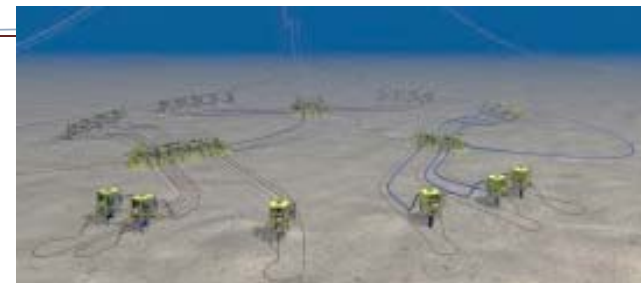
Consultants: (Naval Architecture / Structural)

- Digital Twin (Vessel/Moorings/Risers)(Stress/Fatigue)

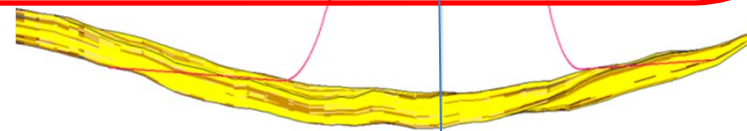
Oil & Gas Operator: Field Operator

- Subsurface Engineering / Reservoir Management
- Production Chemistry
- Well Engineering
- Drilling & Completions
- Logistics & Infrastructure
- Subsea Operating Manual (including Wells)
(in conjunction with Subsea Contractor)
- Subsea /Wells Maintenance/Asset Integrity

SUBSEA



SUBSURFACE



Next Steps

1. Identify the Value (i.e. more oil recovery, reduced operational costs, improved maintenance intervals, etc.) you want to capture;
2. Work backwards to see what kind of analytics are necessary to obtain information (“insights”) to help make the necessary Value “decisions”; also determine where you want to perform the analytics (online/stream/edge or offline/cloud/remote);
3. Work backwards to see what data is necessary (and where to find it) to perform these analytics;
4. Determine how this data needs to be recorded, cleaned, validated, aggregated, and stored for use (“integration”);
5. Implement a Digital Twin, gather data from the necessary instruments, perform analytics, compare actual values with theoretical values, and identify where improvements or actions are needed - then run simulations with the actions implemented – in effect a trial run of the field actions to capture the Value – if everything works, implement the actions.

Thank-you

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